Musical Notation & Representation

Music 253/CS 275a
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5 Jan 2016
Representing Music

Two main categories:

- **For Performance** (used as memory aid and for non-aural transmission)
  
  Usually not a complete representation (some discretion left to performer)
  
  - Usually written, but also Guidonian hand is a spatial representation of music for education and memorization.
  
  Scores for computational performance (usually no discretion left to computer)
  
  - MIDI files, Record, CD, MP3, Data sonification

- **For Analysis**
  
  Usually highlights a specific aspect of the music (reductive)
  
  - Graphical representations (visualizations)
  - Digital representations (computational analysis)
  - Audio-based analysis (such as spectrograms)
Oldest Known Music Notation

Old Babylonian cuneiform musical notation. 2000-1700 BC

2 double columns, each of 7 ruled lines with numbers in Old Babylonian cuneiform tablature notation, with headings, "intonation" and "incantation", respectively.

Two ascending 7-note scales to be played on a 4-stringed lute tuned in ascending fifths.

http://www.schoyencollection.com/music_files/ms5105.jpg
http://www.schoyencollection.com/music.html
Music Notation in Ancient Greece

Oldest complete notated song (~1st century AD)

Seikilos epitaph

Music Notation in Ancient Greece

While you live, shine
Have no grief at all
Life exists only for a short while
And time demands its toll

Performed on a hydraulis: https://www.youtube.com/watch?v=P4_iWkP24Ww#t=7
Music Notation in Ancient Greece

2nd century BC
Earliest surviving composition with a known composer
(Athenios son of Athenios)


3rd century AD

http://en.wikipedia.org/wiki/Oxyrhynchus_hymn

Tonic Sol-Fa

The Lamb.

WILLIAM BLAKE.

GEORGE HENSCHEL.

Lit - tle lamb, who made thee? Dost thou know who

KEY C.

PIANO.

http://en.wikipedia.org/wiki/Tonic_sol-fa
Byzantine Music Notation
(10th – 15th centuries)

Romania, 1823
http://en.wikipedia.org/wiki/Musical_notation#Byzantine_Empire
http://www.musicportal.gr/byzantine_music_system/?lang=en
Gregorian Chant

http://www.schoyencollection.com/music_files/ms1681.jpg

http://en.wikipedia.org/wiki/Gregorian_chant
http://en.wikipedia.org/wiki/Neume
Shape Notes

\[\text{do re mi fa so la ti do}\\
\text{fa so la fa so la mi}\]

STAR IN THE EAST

10, 11.

Baptist Harmony, p. 35

\[\text{Hail the blest morn, see the great Mediator,}\\
\text{Shepherds, go worship the babe in the manger,}\\
\text{Lo, for his guard the bright angels attend.}\\
\text{Caspar, Brightest and best of the sons of the morning!}\\
\text{Down on our darkness, and lend us thine aid;}\\
\text{Star in the east, the horizon adorning, Guide where our infant Redeemer was laid.}\\
\]

2 Child on his cradle the dew-drops are shining;\\
Love lies his bed, with the beasts of the stall;\\
Angels adore him, in slumber reclining;\\
Wise men and shepherds before him do fall.

3 Star, shall we visit him, in costly devotion,\\
Glories of Eden, and offerings divine,\\
Gems from the mountain, and pearls from the ocean,\\
Myrrh from the forest, and gold from the mine.

4 Vainly we offer each ample oblation,\\
Vainly with gold we his favour secure,\\
Richer by far is the heart's devotion;\\
Dearer to God are the prayers of the poor.
Tablature

Indicates *how* to play the pitches, not an abstracted/neutral concept of pitch.

http://en.wikipedia.org/wiki/Tablature

http://www.wikihow.com/Read-Guitar-Tabs
Steel Drum Tablature

— Jonathan Potter, Cardinal Calypso
Koto Tablature

Yamada school notation (Tokyo)

“Rokudan no shirabe”
by Kengyō Yatsuhashi (1614–1685)

Digital representation:

- **koto**
- **kuchi**
- **kern**

* M4/4 * M4/4 * M4/4

=1- =1- =1-

(5+i) te (2d)

- n -

3 ton 4A

1s shan 4d: 4G:

=2 =2 =2

0) . 4r)

{3|sb} sha {8A: 8A#:

3|sc} sha 8A: 8A#:

8| koo 8.a

7| ro 16g

6| rin 8d#

7| o chin 16gH

. . 16ah

=3 =3 =3

1c ton 4d

5| koo 8.d

4| ro 16A#

3| rin 4A)

{1s shan {4d: 4G:

=4 =4 =4

http://en.wikipedia.org/wiki/Koto_%28instrument%29
Piano Tablature

Klavariskoibo

“Keyboard script” in Esperanto

Cornelius Pot

https://www.youtube.com/watch?v=MlolvxunihA&t=659
http://evanlenz.net/blog/2007/11/02/re-discovering-klavariskoibo/
http://en.wikipedia.org/wiki/Klavariskoibo

http://www.klavariskoibo.nl/en
Piano Rolls
Mechanical Representation of music

http://en.wikipedia.org/wiki/Piano_roll
https://www.youtube.com/watch?v=GjpPesy7kIA
Performance Data Visualization

Webern Piano Variations, mvmt. 2, (Op. 27)

Anderszewski 1996

Gould 1954

http://dl.acm.org/citation.cfm?id=2597179
http://mazurka.org.uk/webern/notation/Anderszewski1996
Music Animation Machine

http://www.musanim.com

Stephen Malinowski

https://www.youtube.com/channel/UC2zb5cQbLabj3U9l3tke1pg
https://www.youtube.com/playlist?list=PLMOarqHv8B7P1BuvL2iGqkjS1xNrvTiuX
Music Animation Machine

Bach, Toccata and Fugue in D minor, organ
https://www.youtube.com/watch?v=ipzR9bhei_o

Mozart, Symphony No. 40 in G minor
https://www.youtube.com/watch?v=xvtoqE33iZg

Beethoven, Fur Elise
https://www.youtube.com/watch?v=o0VwTw1eZ1k

Beethoven, String Quartet No. 16, 1st mvt. (opus 135)
https://www.youtube.com/watch?v=Lj4kLPgX5QM

Paganini, Caprice No. 5 (solo violin)
https://www.youtube.com/watch?v=xhc1PsokFOw

Debussy, First Arabesque
https://www.youtube.com/watch?v=Yt1jfX5C1u0

How are musical Dimensions mapped In each visualization?
Textural Notation

Analytic notation of electro-acoustic music

line2sine
Sonification of vector graphics
http://sig.sapp.org/projects/all/line2sine/line2sine/examples

Example 6:

See the music of Iannis Xenakis
http://en.wikipedia.org/wiki/Iannis_Xenakis
Schenkerian Graphs

Edgard Varèse

Pitch reductions for Hyperprism

mm. 1 5 12 15 19 23 27 30 32 34 37 39 44 48 50 53 59 68 72 84 85

http://en.wikipedia.org/wiki/Hyperprism_%28Var%C3%A8se%29
GTTM


http://en.wikipedia.org/wiki/Parse_tree
Keyscapes

Graphical display of harmonic structure

Chopin mazurka in A minor Op. 67, No. 4
https://www.youtube.com/watch?v=AcxZRI6aews

A major: 1:18
A minor: 2:10

Scape plotting domain:

Landscape:

background
large-scale structures
middleground
small-scale structures
foreground
surface features
Computational Key Identification

http://extras.humdrum.org/man/keycor
Computational Key Identification

Pearson correlation:

\[
 r(x, y) = \frac{\sum_n (x_n - \bar{x})(y_n - \bar{y})}{\sqrt{\sum_n (x_n - \bar{x})^2 \sum_n (y_n - \bar{y})^2}}
\]

Krumhansl-Schmuckler key-finding algorithm:

\[
 \text{key}_k = \arg \max_k r(x, y_k)
\]

http://extras.humdrum.org/man/keycor
Computational Key Identification

pitch-class counts (duration weighted):
- C: 8
- D#: 0
- D: 0
- E: 2
- F#: 0
- G: 5
- A: 0
- A#: 5
- B: 2

major keys

best fit: $r = 0.79$
(F minor)

minor key correlations

pitch-class histogram: $x = (8, 0, 0, 0, 2, 11, 0, 5, 7, 0, 5, 2)$
major key prototype: $y_M = (2, 0, 1, 0, 1, 1, 0, 2, 0, 1, 0, 1)$
minor key prototype: $y_m = (2, 0, 1, 1, 0, 1, 0, 2, 1, 0, 1, 0)$
Beethoven Piano Sonata #5 mvmt 1
Sonata No. 5 Internal Key Structure

Theme 1 (C minor):

Theme 2 (Eb major):

Theme 2 (F major):

Theme 2 (C minor):
Other C-Minor Beethoven Sonatas

No. 5:

Piano Sonata no. 8 in C minor, op. 13 ("Pathétique")

piano sonata no. 32
More Info

C++ implementation of KS algorithm and keyscape generator:

- http://extras.humdrum.org/man/keycor
- http://extras.humdrum.org/man/mkeyscape

See bottom of last link for latest keyscape galleries, such as Beethoven string quartets:

http://extras.humdrum.org/man/mkeyscape/beet-quartet

~5000 keyscares of MIDI files:

https://ccrma.stanford.edu/~craig/keyscape/class
Form Visualization/Analysis

http://www.bewitched.com/song.html

Martin Wattenberg

Infinite Jukebox


Paul Lamere
Similarity Matrix
Jonathan Foote


J.S. Bach WTC 1: Prelude #1 in C major